U.S. Department
of Transportation
**Federal Aviation
Administration**

# Advisory Circular

Subject: **OPERATIONS OF AIRCRAFT AT ALTITUDES ABOVE 25,000 FEET MSL AND/OR MACH NUMBERS (Mmo) GREATER THAN .75**

Date: **01/23/91** AC No: **61-107**
Initiated by: **AFS-840** Change:

**1. PURPOSE.** This advisory circular (AC) is issued to alert pilots transitioning to complex, high-performance aircraft which are capable of operating at high altitudes and high airspeeds of the need to be knowledgeable of the special physiological and aerodynamic considerations involved within this realm of operation.

**2. CANCELLATION.** AC 91-8B, Use of Oxygen by Aviation Pilots/Passengers, dated April 7, 1982, is cancelled.

**3. RELATED READING MATERIAL.** Additional information can be found in the latest edition of AC 67-2, Medical Handbook for Pilots.

**4. BACKGROUND.** On September 17, 1982, the National Transportation Safety Board (NTSB) issued a series of safety recommendations which included, among other things, that a minimum training curriculum be established for use at pilot schools covering pilots' initial transition into general aviation turbojet airplanes. Aerodynamics and physiological aspects of high-performance aircraft operating at high altitudes were among the subjects recommended for inclusion in this training curriculum. These recommendations were the result of an NTSB review of a series of fatal accidents which were believed to involve a lack of flightcrew knowledge and proficiency in general aviation turbojet airplanes capable of operating in a high-altitude environment. Although the near total destruction of physical evidence and the absence of installed flight recorders have inhibited investigators' abilities to pinpoint the circumstances which led to these accidents, the NTSB is concerned that a lack of flightcrew knowledge and proficiency in the subject matter of this AC were involved in either the initial loss of control or the inability to regain control, or both, of the aircraft. A requirement has been added to the Federal Aviation Regulations (FAR) Part 61 for high-altitude training of pilots who transition to any pressurized airplane that has a service ceiling or maximum operating altitude, whichever is lower, above 25,000 feet mean sea level (MSL). Recommended training in high altitude operations that would meet the requirements of this regulation can be found in Chapter 1 of this AC.

**5. DEFINITIONS.**

***a. Aspect Ratio*** is the relationship between the wing chord and the wingspan. A short wingspan and wide wing chord equal a low aspect ratio.

***b. Drag Divergence*** is a phenomenon that occurs when an airfoil's drag increases sharply and requires substantial increases in power (thrust) to produce further increases in speed. This is not to be confused with MACH

crit. The drag increase is due to the unstable formation of shock waves that transform a large amount of energy into heat and into pressure pulses that act to consume a major portion of the available propulsive energy (thrust). Turbulent air may produce a resultant increase in the coefficient of drag.

*c. Force* is generally defined as the cause for motion or of change or stoppage of motion. The ocean of air through which an aircraft must fly has both mass and inertia and, thus, is capable of exerting tremendous forces on an aircraft moving through the atmosphere. When all of the above forces are equal, the aircraft is said to be in a state of equilibrium. For instance, when an aircraft is in level, unaccelerated 1 G flight, thrust and drag are equal, and lift and gravity (or weight plus aerodynamic downloads on the aircraft) are equal. Forces that act on any aircraft as the result of air resistance, friction, and other factors are:

(1) ***Thrust.*** The force required to counteract the forces of drag in order to move an aircraft in forward flight.

(2) ***Drag.*** The force which acts in opposition to thrust.

(3) ***Lift.*** The force which sustains the aircraft during flight.

(4) ***Gravity.*** The force which acts in opposition to lift.

*d. MACH,* named after Ernst Mach, a 19th century Austrian physicist, is the ratio of an aircraft's true speed as compared to the local speed of sound at a given time or place.

*e. MACH Buffet* is the airflow separation behind a shock-wave pressure barrier caused by airflow over flight surfaces exceeding the speed of sound.

*f. MACH (or Aileron) Buzz* is a term used to describe a shock-induced flow separation of the boundary layer air before reaching the ailerons.

*g. MACH Meter* is an instrument designed to indicate MACH number. MACH indicating capability is incorporated into the airspeed indicator(s) of current generation turbine-powered aircraft capable of MACH range speeds.

*h. MACH number* is a decimal number (M) representing the true airspeed (TAS) relationship to the local speed of sound (e.g., TAS 75 percent (.75M) of the speed of sound where 100 percent of the speed of sound is represented as MACH 1 (1.0M)). The local speed of sound varies with changes in temperature.

*i. MACH number (Critical)* is the free stream MACH number at which local sonic flow such as buffet, airflow separation, and shock waves becomes evident. These phenomena occur above the critical MACH number, often referred to as MACH crit. These phenomena are listed as follows:

SUBSONIC MACH Numbers below .75

TRANSONIC MACH Numbers from .75 to 1.20

SUPERSONIC MACH Numbers from 1.20 to 5.0

HYPERSONIC MACH Numbers above 5.0

*j. MACH Speed* is the ratio or percentage of the TAS to the speed of sound (e.g., 1,120 feet per second (660 Knots (K)) at MSL). This may be represented by MACH number.

*k. MACH Tuck* is the result of an aftward shift in the center of lift causing a nose down pitching moment.

*l. Mmo (MACH, maximum operation)* is an airplane's maximum certificated MACH number. Any excursion past Mmo, whether intentional or accidental, may cause induced flow separation of boundary layer air over the ailerons and elevators of an airplane and result in a loss of control surface authority and/or control surface buzz or snatch.

*m. Q-Corner or Coffin Corner* is a term used to describe operations at high altitudes where low indicated airspeeds yield high true airspeeds (MACH number) at high angles of attack. The high angle of attack results in flow separation which causes buffet. Turning maneuvers at these altitudes increase the angle of attack and result in stability deterioration with a decrease in control effectiveness. The relationship of stall speed to MACH crit narrows to a point where sudden increases in angle of attack, roll rates, and/or disturbances; e.g., clear air turbulence, cause the limits of the airspeed envelope to be exceeded. Coffin corner exists in the upper portion of the maneuvering envelope for a given gross weight and G-force.

*n. Vmo (Velocity maximum operation)* is an airplane's indicated airspeed limit. Exceeding Vmo may cause aerodynamic flutter and G-load limitations to become critical during the dive recovery.

## 6. DISCUSSION.

*a. FAR Part 61* prescribes the knowledge and skill requirements for the various airman certificates and ratings, including category, class, and type ratings authorized to be placed thereon. The civil aircraft fleet consists of numerous aircraft capable of flight in the high-altitude environment. Certain knowledge elements pertaining to high-altitude flight are essential for the pilots of these aircraft. Pilots who fly in this realm of flight must receive training in the critical factors relating to safe flight operations in the high-altitude environment. These critical factors include knowledge of the special physiological and/or aerodynamic considerations which should be given to high-performance aircraft operating in the high-altitude environment. The high-altitude environment has different effects on the human body than those experienced at the lower altitudes. The aerodynamic characteristics of an aircraft in high-altitude flight may differ significantly from those of aircraft operated at the lower altitudes.

*b. Pilots who are not familiar with operations in the high-speed environment* are encouraged to obtain thorough and comprehensive training and a checkout in complex high-performance aircraft before engaging in extensive high-speed flight in such aircraft, particularly at high altitudes. The training should enable the pilot to become thoroughly familiar with aircraft performance charts and aircraft systems and procedures. The more critical elements of high-altitude flight planning and operations should also be reviewed. The aircraft checkout should enable the pilot to demonstrate a comprehensive knowledge of the aircraft performance charts, systems, emergency

procedures, and operating limitations, along with a high degree of proficiency in performing all flight maneuvers and in-flight emergency procedures. The attainment of such knowledge and skill requirements by a pilot of high-performance aircraft should enhance the pilot's preparedness to transition to the operation of a high-speed aircraft in the high-altitude environment safely and efficiently.

7. **SUMMARY.** It is beyond the scope of this AC to provide a more definitive treatment of the subject matter discussed herein. Rather, this AC will have served its purpose if it aids pilots in becoming familiar with the basic phenomena associated with high-altitude and high-speed flight. Pilots should recognize that greater knowledge and skills are needed for the safe and efficient operation of state-of-the-art turbine-powered aircraft at high altitude. Pilots are strongly urged to pursue further study from the many excellent textbooks, charts, and other technical reference material available through industry sources, and to obtain a detailed understanding of both physiological and aerodynamic factors which relate to the safe and efficient operation of the broad variety of high-altitude aircraft available today and envisioned for the future.

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